A Standard for the 90s:
IEEE C62.41 Surges Ahead

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Reprinted from *Compliance Engineering,* Fall 1991

Significance
Part 6: Tutorials, textbooks, and reviews

A trade magazine article publicizing the release by IEEE of the updated version of the seminal IEEE Std 587-1980 (a.k.a C62.41-1980).

A Standard for the 90s: IEEE C62.41 Surges Ahead

The Recent Upgrade of This Key IEEE Standard Reflects the Growing Interest Over Power Line Surges

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With each year that passes, we are relying more and more on electronics in our lives, at home, at work, for travel, for defense... the list is endless. Reliability of these electronic systems is essential, and this in a context of increased sophistication which often brings about more susceptibility to disturbances. Thus, immunity to electromagnetic disturbances, including surges in the power line, is a must.

Designers and users perform surge testing to verify that, indeed, their equipment is immune to these surges. The question, however, is what level of immunity must be achieved, since there are engineering tradeoffs to be made, as well as economic considerations. Depending on the type of equipment (its mission) and the location where it will be used, a moderate or very high degree of immunity is appropriate. To select the appropriate level of surge stress and to perform surge testing in a manner that will yield valid results while ensuring safety, reliable guidance is needed.

Ten years after its first publication as IEEE Standard 587, the *Guide on Surge Voltages in Low Voltage AC Power Circuits* (now ANSI/IEEE C62.41-1980) has undergone a major transformation into a Recommended Practice format. From a guide proposing two basic waveforms to represent typical surges, the document now proposes consideration of two standard waveforms (the old friends of 1980) complemented by three additional waveforms, one a fast burst, the others longer, high-energy surges.

A History of IEEE C62.41

Actually, the occurrence of surges that led to the launching of a small working group in 1966 to develop IEEE 587 have not changed much, although the electronic equipment affected by surges as well as the standard-writing group have undergone considerable changes. The initial effort to provide guidance for designers on surges in low voltage circuits was started by Dave Bodle [1], who persuaded a small group of concerned fellows to seek a home in the IEEE Surge-Protective Devices Committee (a body which, at the time, was mostly concerned with the high voltage world of electric utilities). This pioneer group set out to collect published data on surge occurrences and even circulated among its members a set of six peak-reading surge counters donated by one sponsor to add to its data base. These were the days before the explosive development of disturbance monitors cum graphics. And so, IEEE 587 was born in 1980, with great expectations that it would be a useful guide for designers and users of electrical and electronic equipment.

Alas, there were no other documents available to guide those users in selecting severity levels from the choice proposed by IEEE 587. In particular, the citation of 6kV being a practical upper limit for the occurrence of surges in 120-V circuits was soon misconstrued as implying a requirement that all equipment should be designed to withstand 6kV surges. Product specification sheets began to state 'meets IEEE 587,' forgetting the difference between a standard and a guide in IEEE parlance. In the meantime, the guide was renumbered ANSI/IEEE C62.41, as part of a family of surge-related documents [2] but the '587' label has stuck and is even found in the model names of several commercial surge generators.

In a first attempt to help users make sensible and correct decision on surge testing, the IEEE working group developed a Guide on Surge Testing - ANSI/IEEE C62.45-1987. The Guide provided information on how to conduct reliable and safe surge tests ("Don't kid yourself, don't kill yourself!"), also pointing out how to interpret the concepts of locations categories proposed in the original document. However, the questions and misuse by some continued, so the working group resolved to update the guide.

Normally, IEEE procedures require a 5-year cycle of reaffirmation or revision but the challenge of reviewing new data and developing consensus on this subject stretched the work into ten years, culminating in a Recommended Practice that was approved early in 1991 and is now available from IEEE. From a group of 12 people in 1980, the working group grew to 29 by 1990, reflecting the growing interest about surge protection among users and manufacturers of electronic equipment. Reconciling the different points of view from the enlarged group has produced a new document that should receive even better acceptance than the original 1980 version and, hopefully, result in fewer misunderstandings.

Toward a More Useful Standard

One of the first difficulties was to arrive at a satisfactory agreement of what the word 'surge' means; to some a surge is a temporary increase in the AC line voltage. That meaning is now replaced by the term 'swell,' although a sizeable fraction of the engineering community will continue to use the word surge with that meaning.

Next came the issue of noise versus surges (spikes, etc.). How big must a voltage change be to become a surge? That issue was in fact not resolved; instead, a conceptual figure was included in the document to show the relationships among several parameters (see Figure 1) and thus leave the bottom end of the range open to appropriate interpretation depending on the circumstances. In addition, the single-value upper limit of voltages proposed in the 1980 version has been replaced by a table featuring three levels for each waveform, according to the location category or the system exposure. The menu of waveforms proposed in the 1991 version is new and, hopefully, improved, and includes the following types:

- The 0.5 μs - 100 kHz Ring Wave, defined in the 1980 version, as standard waveform.
- The Combination Wave, 1.2/50 μs - 8/20 μs, also from 1980, as standard waveform.
- The EFT Burst (5/50 ns), adopted from IEC 801-4, as additional waveform.
- A new 10/1000 μs Wave, for high-energy stress, as additional waveform.
- A new 5 kHz Ring Wave, for capacitor switching transient, as additional waveform.

The rationale for proposing standard and additional waveforms is rooted in the acceptance of the 1980 waveforms as being representative and useful, while recognizing that other waveforms may be encountered in specific cases and should be recognized. However, the wish for complete representation of all surges that may occur has to be tempered by economics and engineering judgment; hence, the split between standard (recommended) and additional (suggested). Figure 2 shows all five waveforms, and Table 1 presents a summary of the voltage and impedance values. The new waveforms are proposed in response to emerging concerns on surge occurring in specific environments. Thus, a brief discussion of these three new waveforms is in order

Additional Waveforms Address Emerging Concerns

The EFT Burst has been developed by Technical Committee 65 of the International Electrotechnical Commission (IEC) to provide a screening test for susceptibility to the fast transients that can be induced in power as well as data lines by the multiple re-ignitions occurring during the opening of a circuit by a contactor. While this type of contactor is mostly found in industrial environments (the world of TC65), other systems can have the same exposure (at least until the day when all power switching will be done by bounce-free, restrike-free solid-state relays). The catch, however, is that this test waveform was proposed to evaluate immunity of equipment by a test procedure that involves coupling the burst into the equipment under test by a capacitance divider: the coupling capacitor and the internal capacitance of the equipment under test. It does not mean that the 1-4kV surges involved in this test necessarily occur in the power systems; what it means is that equipment that passes the high severity test will most likely be immune to what the real world does to connected equipment. One should not lose sight of this fundamental aspect of test standards; it is impossible to duplicate all possible occurrences in one test, but if a test can be developed so that equipment that passes the test has better field performance than equipment that fails the test, then the test is a valuable tool for reliable design.

The 10/1000 µs Wave has been proposed to provide a means to stress equipment with high-energy surges, such as those that can occur during major power-system fault clearing. The data base for that waveform is somewhat limited, so a range of peak levels and source impedance is proposed, to be selected according to the particulars of the situation. As one check for reality, the energy deposition capability of this waveform is such that small varistors (14-mm diameter or less) in common use - by the millions - could only withstand a few applications of that surge. Thus, we know that such a high-energy surge does not occur very often.

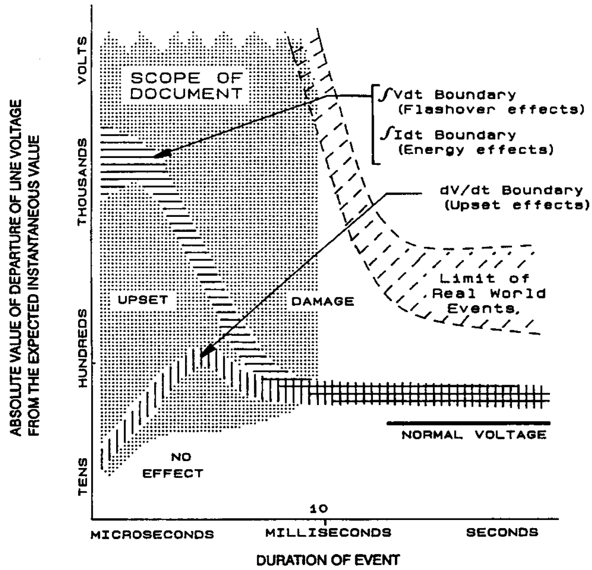
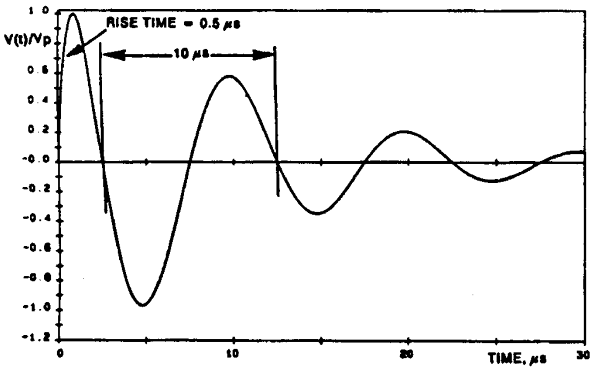
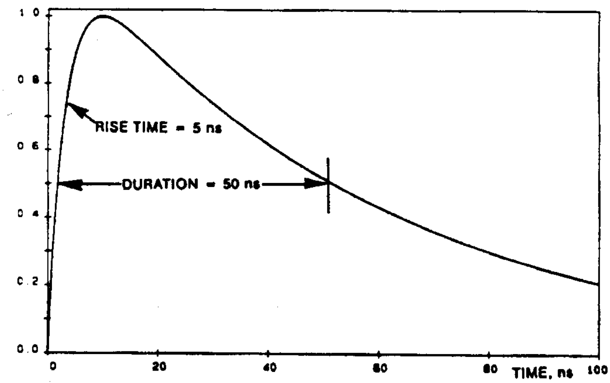


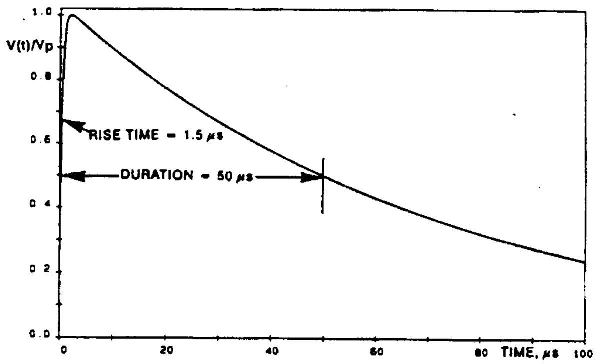
FIGURE 1: Simplified Relationships Between Voltage, Duration, Rate of Change and Their Effects on Equipment. (All figures in this article reproduced from IEEE Std C62.41-1991, "Recommended Practice on Surge Utilities in Low-Voltage AC Power Circuits." Copyright © 1991 by the Institute of Electrical and Electronics Engineers, Inc., with the permission of the IEEE.)



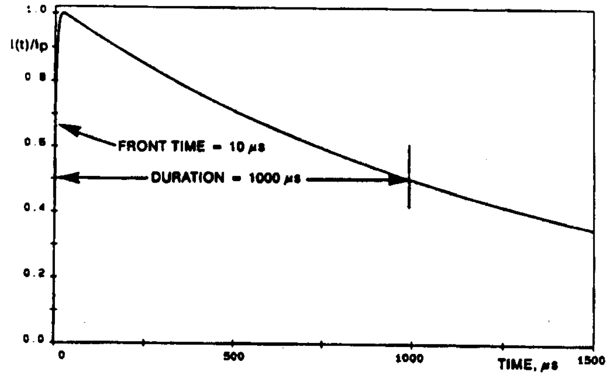
100 kHz Ring Wave



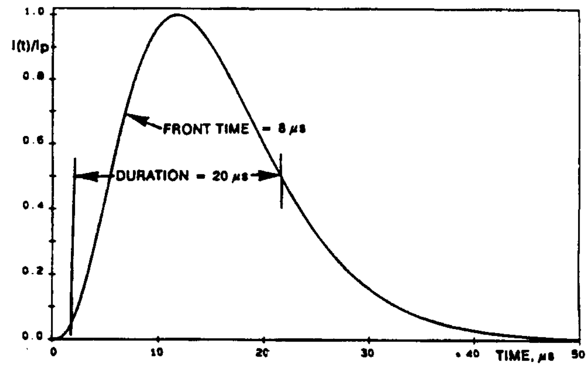
Waveform of a pulse in the EFT burst



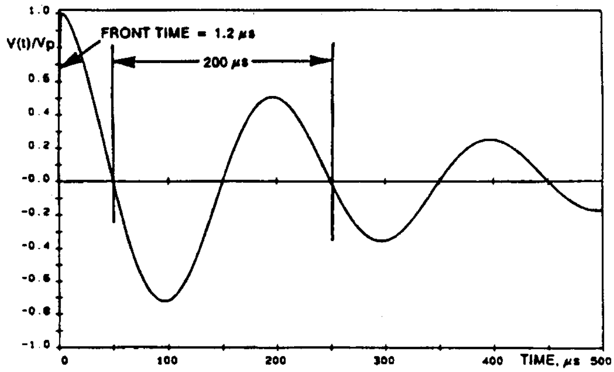
Combination Wave, Open-Circuit Voltage



Waveform for the 10/1000 μs current surge



Combination Wave, Short-Circuit Current



Waveform for 5 kHz Ring Wave

FIGURE 2

Location Category *	System Exposure **	Standard Waveforms				Additional Waveforms					
		100 kHz Ring Wave		Combination Wave		EFT Burst		10/1000 Wave		5 kHz Ring Wave	
		V (kV)	Z (Ω)	V (kV)	Z (Ω)	V (kV)	Z (Ω)	V (pu)***	Z (Ω)	V (pu)***	Z (Ω)
A1	Low	2	30	None		1	50	None		None	
A2	Medium	4	30	None		2	50	1.0	1	1.0	1 to 5
A3	High	6	30	None		4	50	1.3	0.25	1.8	0.5 to 1
B1	Low	2	12	2	2	1	50	None		None	
B2	Medium	4	12	4	2	2	50	1.0	1	1.0	1 to 5
B3	High	6	12	6	2	4	50	1.3	0.25	1.8	0.5 to 1
C1	Low	None		6	2	None		None		None	
C2	Medium	None		10	2	None		1.0	1	1.0	1 to 5
C3	High	None		20	2	None		1.3	0.25	1.8	0.5 to 1

* Location Category A is end of "long" branch circuits.
Location Category B is service entrance and "short" branch circuits
Location Category C is outside of building

** System exposure levels reflects environment factors: lightning activity, power system switching, etc.

*** Voltage in per-unit of the peak of the mains voltage, added at the peak of the sine wave

Table 1: *Peak Surge Levels (V) and Source Impedances (Z) in C62.41-1991.*

The 5 kHz Ring Wave has been proposed to represent the situation encountered near large power-factor correction capacitor banks. Switching transients in the range of 500 to 1000 Hz can occur, with high-energy capability. In this case, the data base is rich in computer simulations and anecdotal recordings but it is difficult to make an accurate prediction for the general case because the actual transients depend entirely on the local situation. It will be up to manufacturers and users to agree on a compromise between conservative overdesign wishes and economic viability of the design.

Waveform Selection Supports International Harmonization Efforts

The waveforms presented in the new Recommended Practice document should also be a positive step toward harmonization with international standards. The Combination Wave is consistent with the conventional 'impulse' typical of IEC surge testing; the EFT Burst represents the adoption of an existing IEC Standard. Conversely, the 100 kHz Ring Wave, long resisted by some of the IEC Committees, is beginning to gain a foothold in the IEC community. The 10/1000 µs Wave could be an alternative to the 100/1300 µs surge 'under consideration' in some of the IEC TC 77 surge immunity drafts. (This 100/1300 µs surge is a varistor killer and, therefore, should not be considered beyond its original scope of application which is heavy industrial environments where faults are cleared by fuses(5)). The 5 kHz Ring Wave has yet to gain international recognition.

To assist designers in making computer simulations, the Recommended Practice document provides equations for the waveforms, and tolerances are also specified. This detailed information might be better located in the *Guide on Surge Testing* but it was included in the Recommended Practice document until such time as a revised guide on surge testing will include it (that revision has just been initiated, and it will probably take another year before the revision is in print).

Last but not least, the new Recommended Practice document has three appendices that offer tutorial discussions of the concepts used in the document, provide information on the data base, and list almost 100 bibliographic citations, with brief notes on the contents of the papers. Thus, readers of the Recommended Practice will have on hand a short course on how to be prepared to deal with surges in low voltage AC circuits.

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The author acknowledges the five-year effort in consensus building by the members of the working group and other interested parties that made possible the revision of IEEE 587 into a Recommended Practice.

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